The WATERS Network:

An MREFC Initiative involving three NSF Directorates:
Engineering,
Geosciences,
Social, Behavioral & Economic Sciences

The overarching question

- How do we establish a framework to more reliably predict and manage water quantity and quality in the U.S. as climate changes, populations grow, land use evolves, and individual and societal choices are made?
  - How will regional-scale fresh water availability and demand change in the future?
  - How will human behavior, land-use change, and the water management infrastructure interact with supply to affect the quality of water?

Status as NSF MREFC "horizon" project
(Major Research and Equipment Facilities Construction)

- This year: produce compelling science plan
  - Draft 15 May for review by NRC
  - Then respond to review
- Conceptual design (2-3 years)
  - Requirements definition, prioritization, review
  - Identify critical enabling technologies and high risk items
  - Top-down parametric cost and contingency estimates and risk assessment
  - Draft Project Execution Plan
- Preliminary design/ readiness stage
  - NEON is at this stage
- National Science Board approves – final design
- **Construction and Commissioning**
  - From MREFC account
- Operation and maintenance
  - From Directorates
- Renewal/termination

Team members

- Co-Investigators
  - John Braden, Illinois
  - Rick Hooper, CUAHSI
  - Barbara Minsker, Illinois
  - Jerry Schnoor, Iowa
- Senior Investigators
  - Roger Bales, UC Merced
  - Martha Conklin, UC Merced
  - Nick Clesceri, RPI emeritus
  - Lou Derry, Cornell
  - Tom Harmon, UC Merced
  - Anna Michalak, Michigan
  - James Mihelcic, South Florida
  - Sandra Schneider, South Florida
  - David Tarboton, Utah State
  - Jeanne VanBriesen, CMU
  - Peter Wilcock, JHU

Would WATERS Network have helped in Iowa, June 2008?

- New, experimental rain radar would provide better precipitation measurements
- Lidar altimetry data would enable much better prediction of flooded areas
- Better models of flood plain, sewage collection and bypass systems
  - to estimate runoff loadings of *E coli* and fecal coliform bacteria
  - warn about wading hazard

- Questions:

  How will flood probabilities and associated inundation areas change as climate and land use change?

  Could flood damage be minimized or prevented with this additional knowledge?

Gulf of Mexico Hypoxia Caused by Runoff from Mississippi Basin

In 2007, dead zone was 21,000 km^2.

What will be the impacts of targeted BMPs and/or changes in centralized and decentralized treatment?

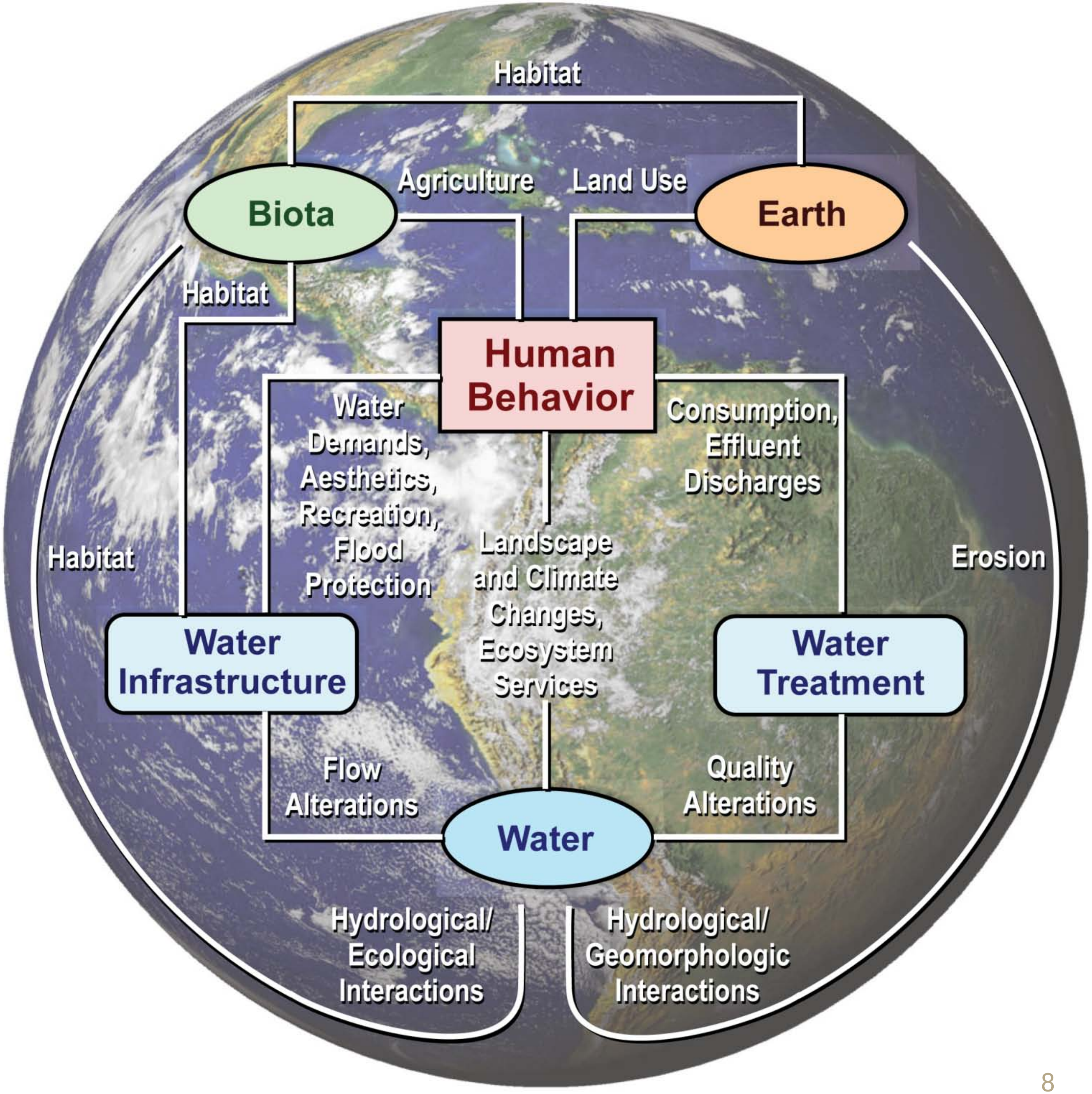
Rapid growth followed 1993 floods. What will 2008 bring?

Mississippi River meets the Gulf of Mexico
(Source: http://www.gulfhypoxia.net)

Premise for the WATERS Network

- Newly designed, national sampling strategy that integrates
  - extant in situ and remotely sensed data
  - new measurements, analyses, and experiments at a realistic number of facilities and representative basins
  - extension to large scales and to all regions through models, synthesis, remote sensing, and cyberinfrastructure
  - education and outreach, citizen science, and interaction with stakeholders
- Requires close collaboration with Federal, state, and local agencies and citizen groups

- Domain
  - pristine, rural, and urban areas
  - constructed networks and facilities for management and treatment
- Prediction
  - episodes like floods and stormwater overflows
  - seasonal events like snowmelt runoff and surges of agricultural wastes
  - projections over multiple generations



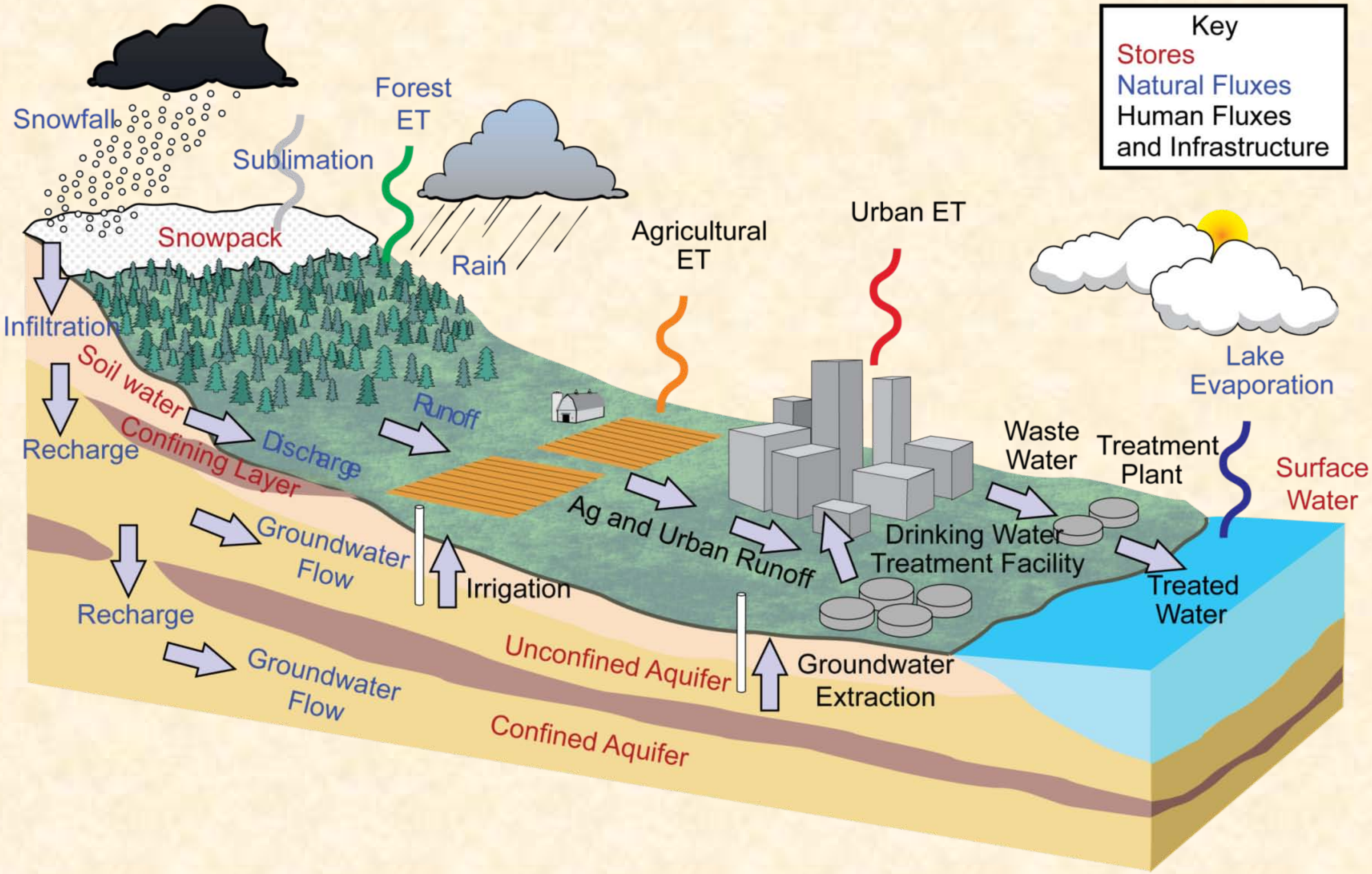
Four science/technology themes emerge

- Variables and their scales and precision that we should predict
- Scaling of measurements from plots and facilities to large basins, and transfer of findings and capabilities from one area to another
- Behavior of coupled human-natural systems, including engineered systems
- Incorporation of emerging technologies and experimental facilities

Need for the WATERS Network

- Current practices do not now predict water quantity and its constituents accurately enough for effective management
  - Despite past investments, financial losses and personal injury from drought, flood, and pollution occur
- Current empirical methods were developed over a period when human impacts were isolated and climate was more stable
  - In addition to spatial and temporal variability, we face a different future water environment caused by population growth, land use modification, and climate change
- We need a more mechanistic approach

Typical WATERS Network scope



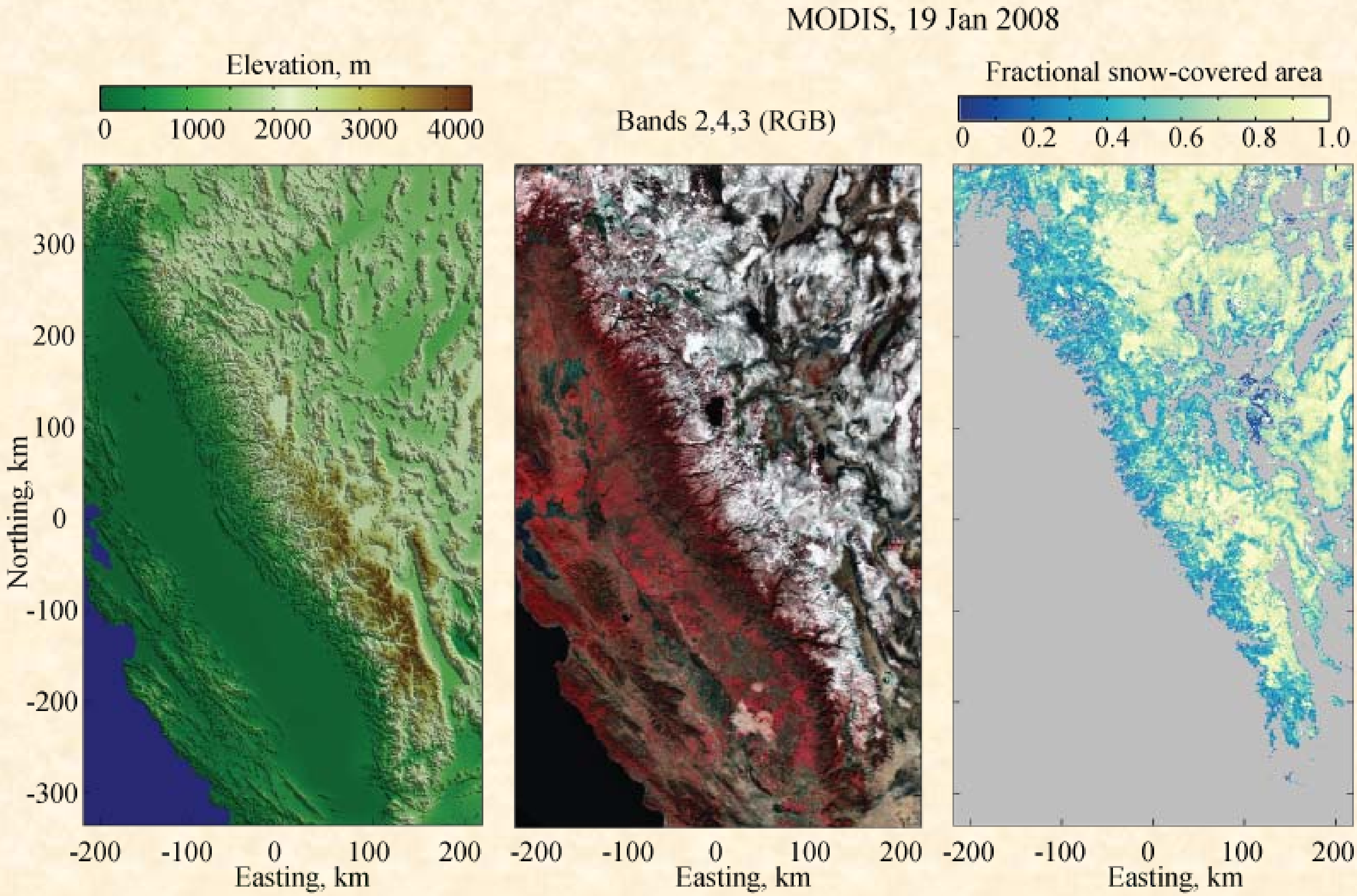
“What to predict?” is an interdisciplinary question

- What beneficial decisions can we make based on a prediction, as compared to decisions without the prediction?
  - Need to understand and predict interactions among heterogeneous processes (e.g. land use and climate change) at many scales that produce the spatially and temporally variable quantity and quality of water
  - Thereby informing options for management and engineering design
  - Requires understanding of human information processing and the role of scientific information in decision making
  - Help evaluate trade-offs among temporal and spatial scales, accuracy, and uncertainty of predictions

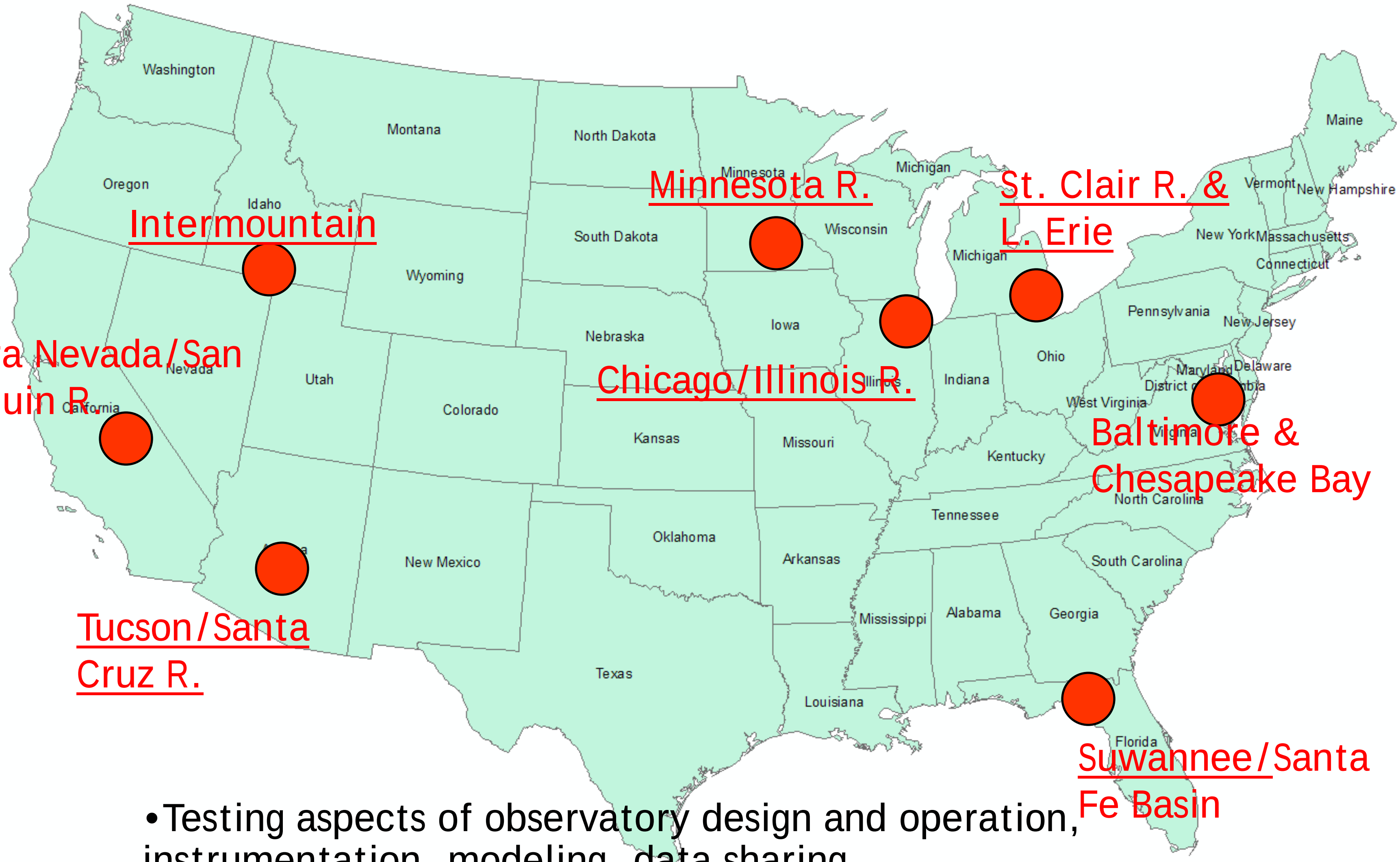
Scaling and transferability

- Research in testbeds is improving our ability to understand and predict from detailed measurements to the scale of a large basin
- NSF is currently funding 11 two-year “test-bed” projects to gain field experience with sensor deployment and operation, along with related projects
  - Critical Zone Observatories (CZO)
  - CyberInfrastructure for Environmental Observatories: Prototype Systems (CEOPS)
  - Materials Use: Science, Engineering and Society (MUSES)

Remote sensing example: fractional snow-covered area from MODIS



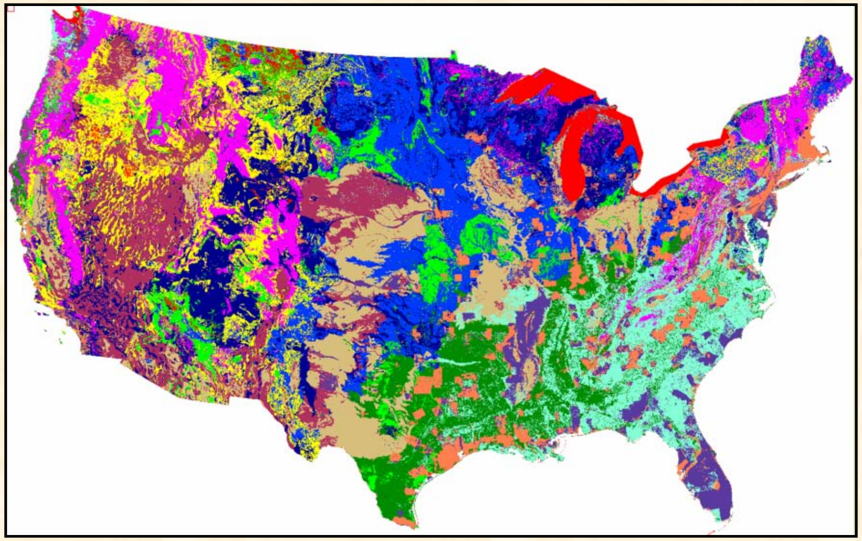
Illustrative testbed sites: (Funding through direct NSF applications)



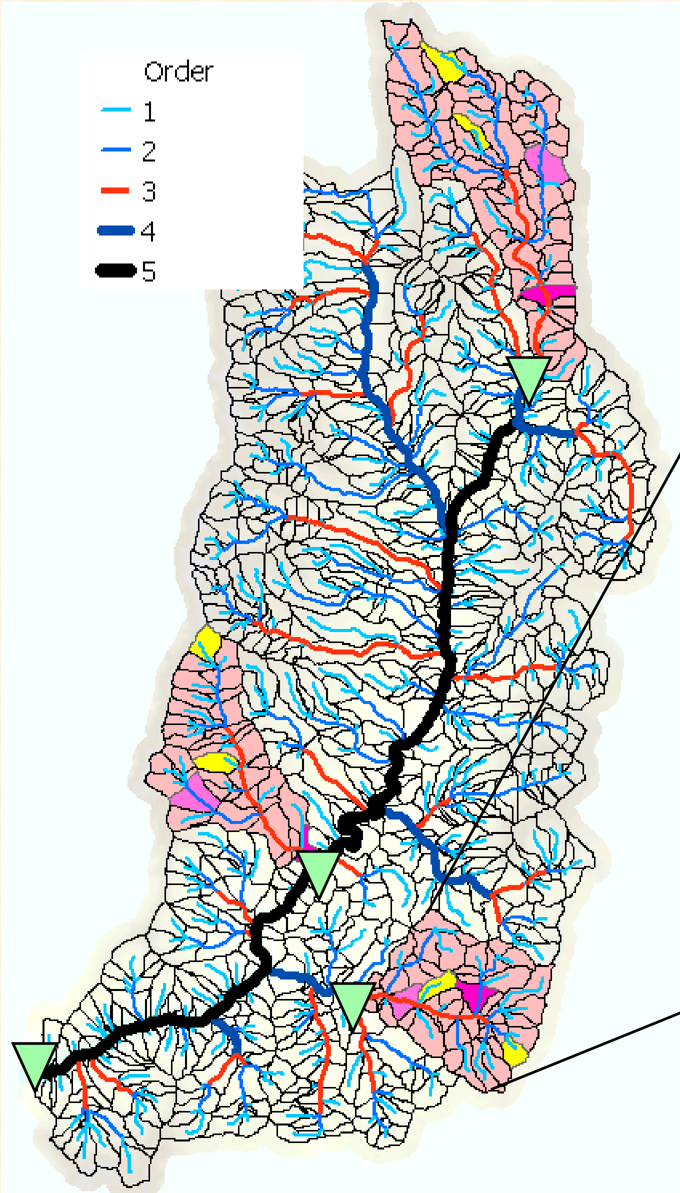
- Testing aspects of observatory design and operation, instrumentation, modeling, data sharing

Define “similar” environments for sampling design

- Divide country into “similar” areas that are comparable and can intensively studied at one site
  - Capture the diverse hydrologic conditions that exist across the U.S.
  - Set of variables that quantify hydrologic setting, both physical and human influenced
- Example: Stratified sampling based on the Human Influenced Water Resource Classification (HIWRC)

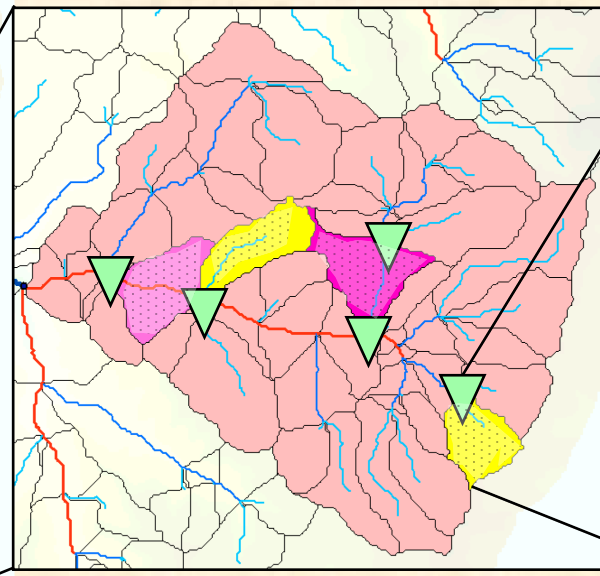


Nested design

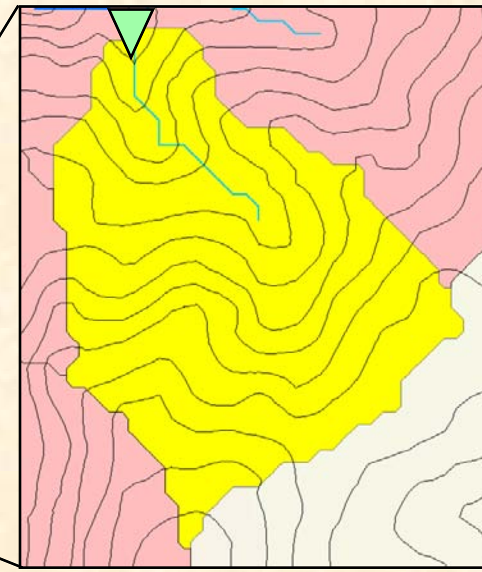


5th order basin

3rd order Cluster containing catchments draining directly to 1st, 2nd and 3rd order streams



1st order catchment

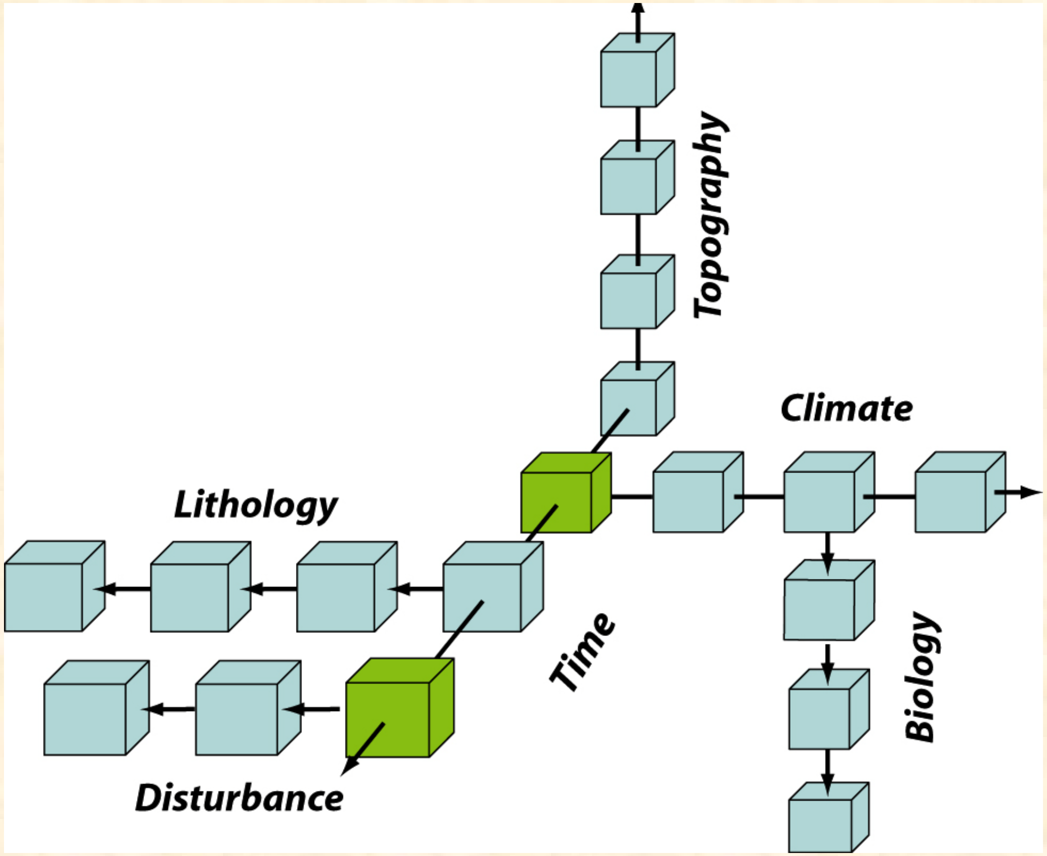


Terrestrial sensor package over catchment

Stream sensor package

Gradient design

Systematic data collection across gradients to allow isolation of individual causative factors



Models to consider (not exhaustive)

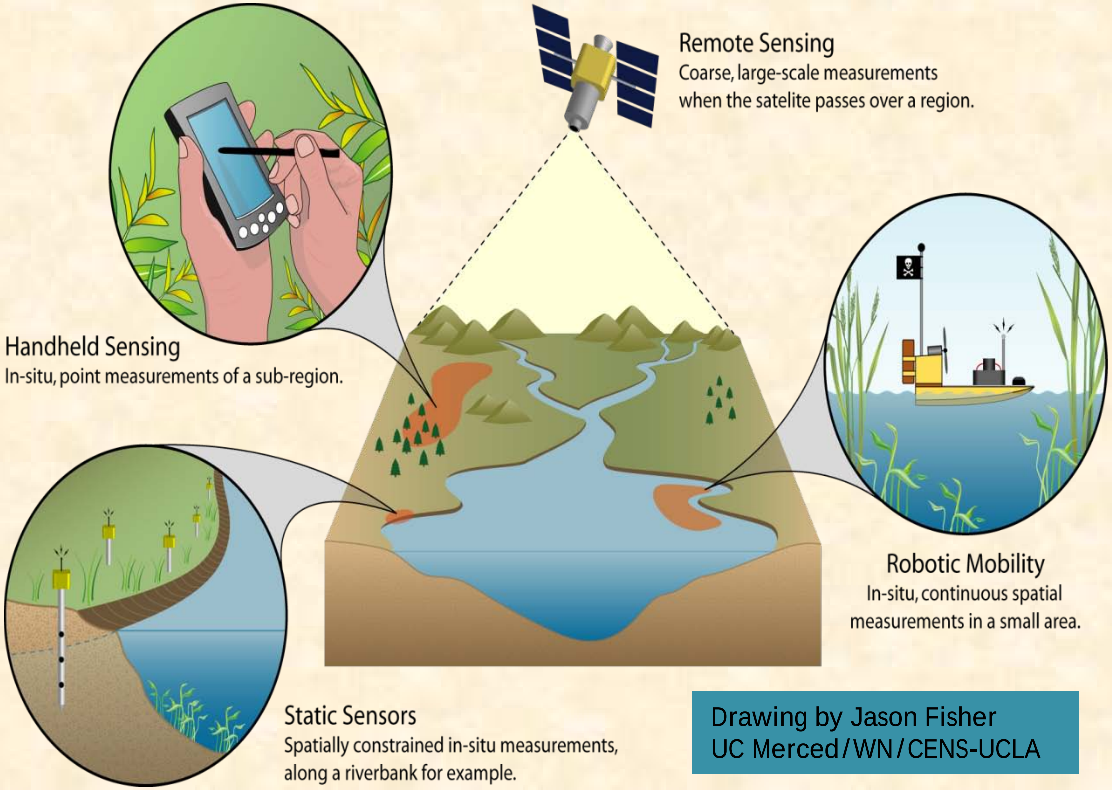
- Water and wastewater infrastructure
  - GPS-X, EPANET, Waterspot
- Grid-scale hydrologic models
  - DHSVM, HYDRUS, ParFlow, SLIM, PIHM, RHESSys
- Basin-scale models
  - HSPF, QUAL2K, SAC-SMA, SWAT, SWMM, THREW, VIC

Behavior of coupled human-natural systems

- Important links between natural and human components
  - Human component includes engineered systems, which impose their own spatial and temporal variability on water and its constituents
- The ways that humans and their institutions use and interpret scientific information to make decisions is a fundamental question in social science
  - And the findings feed back to the hydrologic science and environmental engineering to help focus goals for the new knowledge needed
- Example question: How do institutions that manage water quality emerge and evolve in response to environmental stresses and social dynamics?

Innovative technologies and experimental facilities

- Fixed or mobile pilot water/wastewater treatment facilities
- Instrumented drainage basins
- Experimental streams & watershed facilities
- Incorporate new sensor technology
- Cyberinfrastructure
  - Manage the input data and data products
  - Run coupled models and analyze ensembles



Drawing by Jason Fisher
UC Merced/WN/CENS-UCLA

Collaboration with other MREFCs

- Need to understand interactions between water and ecology (NEON)
- Understanding coastal margins requires interactions with oceanographers (OOI)
- Any activities in Arctic regions could be collaborations with AON
- Collaborations could involve:
  - Data sharing
  - Joint research and E&O activities
  - Overlap of sites

The WATERS Network—Intellectual Merit

- Understand and predict interactions between heterogeneous processes at different scales that produce the variability found in the water environment

- Thereby inform options for management and engineering design
- Requires understanding of human information processing and the role of scientific information in decision making

- Help evaluate trade-offs among temporal and spatial scales, accuracy, and precision of predictions
- (What beneficial decisions can we make based on the prediction, as compared to decisions without the prediction?)

Conclusions

- Transformative science and engineering
  - Predictive power, including engineered and hydrologic systems
  - Integration of disciplines across NSF directorates (GEO, ENG, SBE)
- Why a Network?
  - Stratified sampling approach must be integrated across nation
  - Theory and models must be location-independent
  - Significant inter-agency and inter-organizational collaboration to move new research findings into operational practice
- Broader impacts to society, allied disciplines, and education and outreach

MREFC management issues

- Boundary conditions
  - No MREFC precedent for a such a broad multi-disciplinary consortium
  - Hydrologic sciences community already has a formal consortium (CUAHSI), but other communities do not
  - Water research and management are performed by many federal, state, interstate, and local governmental bodies
- Need to keep communities engaged, so selection of participants must be transparent
- To implement, WATERS Network must integrate with mission agencies (federal, state, local)
  - Common research interests with WN
  - Needs and expertise that support strong:
    - Problem-driven basic research
    - Research-driven problem solving
  - Extensive existing facilities and data collection efforts to leverage